

## EUROPEAN DIESEL FUEL - A REVIEW OF CHANGES IN PRODUCT QUALITY 1986-1989

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### Introduction

In Europe heavy goods vehicles are effectively 100% diesel engined. This coupled to the significant percentage of diesel powered passenger cars and light duty commercial vehicles results in Europe having the highest penetration of diesel engined vehicles worldwide (Fig 1). Despite the increasingly stringent emission limits and customer performance demands, technological advances by the diesel engine manufacturers are enabling them to keep up with such rapid change. Thus the position of the diesel engine appears secure in Europe, provided consistently high quality road diesel fuel is maintained.

The European refiner is facing a steady increase in demand for road diesel together with a decline in heating/off road gas oil volumes (Fig 2) due to competition from gas and other forms of energy. This is putting pressure on refiners to include greater proportions of cracked gas oils in the road diesel pool with the potential for stability problems - a major area of shortcoming for conversion distillate streams.

Gas Oil/Diesel Demand W. Europe  
(1980 - 1995)

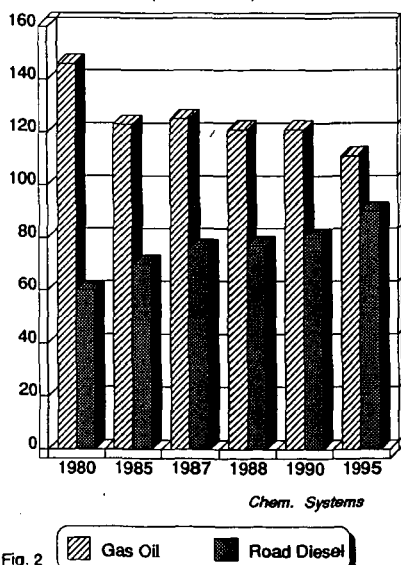


Fig. 2

Engine Production 1986

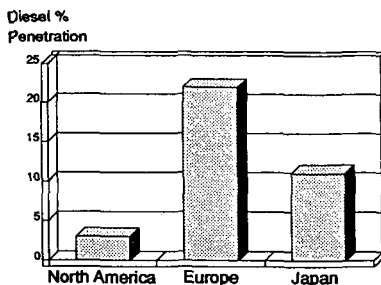


Fig. 1

This paper reviews the results of systematic winter surveys of road diesel fuel in Europe carried out from 1986-89 in which oxidative and thermal stability were evaluated along with other key parameters of diesel fuel quality.

### Diesel Fuel Specifications

In Europe unleaded gasoline is unique in having a common specification from country to country. The national diesel fuel specifications detailed in Appendix 1 follow no set pattern with the exception of low temperature properties. These are consistent with the demands of geography. This lack of commonality of quality is a major concern to trans European operators of diesel vehicles. Likewise only the UK contains any stability standard and that a somewhat relaxed 2.5 mg/100 ml maximum in the ASTM D2274.

From the 1986-89 Ethyl diesel fuel surveys (Refs 1-3 and Appendix 2) consideration will only be given to the following primary diesel fuel properties

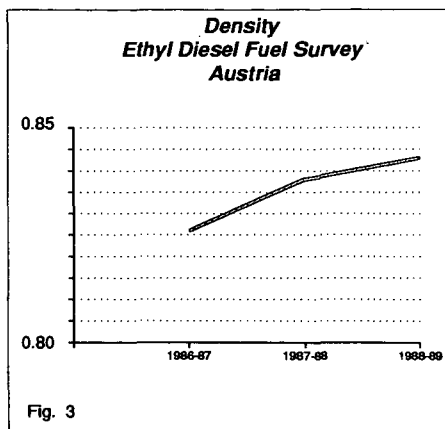
- |                  |                        |
|------------------|------------------------|
| 1) Density       | 5) Sulphur Content     |
| 2) Cetane Number | 6) Aromatics Content   |
| 3) Cetane Index  | 7) Olefin Content      |
| 4) Viscosity     | 8) Oxidative Stability |
|                  | 9) Thermal Stability   |

Of these cetane number, oxidative stability and thermal stability can be improved by use of a suitable multifunctional diesel fuel additive package. The other primary features are purely influenced by refinery processing.

## Density

The density of a diesel fuel affects the mass of fuel entering the combustion chamber and thus impacts on engine power, fuel economy and emissions.

The average density across Europe is essentially unchanged over the 3 years (Table 1). Even when individual countries are considered there is little annual variation. Austria is the only exception where density has risen steadily with time (Fig 3). This is coupled to a 17°C increase in the 50% distillation point and a smaller increase in end-point indicating a change in demand balance (Appendix 2).



## Ethyl European Diesel Fuel Winter Survey Overall Mean Values

| <b>Table 1</b>                                 | <b>1986-87</b> | <b>1987-88</b> | <b>1988-89</b> |
|--|----------------|----------------|----------------|
| Density @ 15°C (g/cm <sup>3</sup> ) ASTM D4052 | 0.8380         | 0.8388         | 0.8368         |
| Cetane Number, ASTM D613                       | 51.3           | 51             | 52.5           |
| Cetane Index, ASTM D976                        | 51.2           | 50.4           | 51.3           |
| Viscosity @ 20°C, ASTM D445                    | 4.36           | 4.22           | 3.99           |
| Sulphur, % weight, ASTM D4294                  | 0.24           | 0.27           | 0.24           |
| Aromatics, % vol ASTM D1319                    | 29.2           | 32.1           | 26.9           |
| Olefins, % vol ASTM D1319                      | 0.6            | 1.6            | 3.8            |
| Oxid. Stability, mg/100 ml, ASTM D2274         | 1.3            | 1.0            | 0.6            |
| Pad Test, Rating                               | 12*            | 7.5            | 5              |
| *only 10 results.                              |                |                |                |

## Cetane Number

Cetane Number is a measure of fuel ignition delay. This we consider to be the time between start of fuel injection and the rapid rise in pressure in the pre-chamber. Many other definitions are sometimes used (Ref 4).

Cetane number defines the ease of auto-ignition of the fuel. Whilst this is generally a reflection of the inherent stability of the molecules in a fuel, ignition improvers are often included to enhance performance.

Despite all the predictions of declining cetane quality due to increasing demand the overall picture in Europe is the reverse (Table 1). This is due to the introduction of premium quality diesel fuels containing multifunctional additives which can include cetane improver. This is most dramatically seen in West Germany (Fig 4) where premium diesel fuel was introduced in 1987 in response to OEM demands for higher quality fuels to reduce environmental emissions. As we discuss the other parameters the impact of this quality enhancement of diesel fuels will be further evidenced.

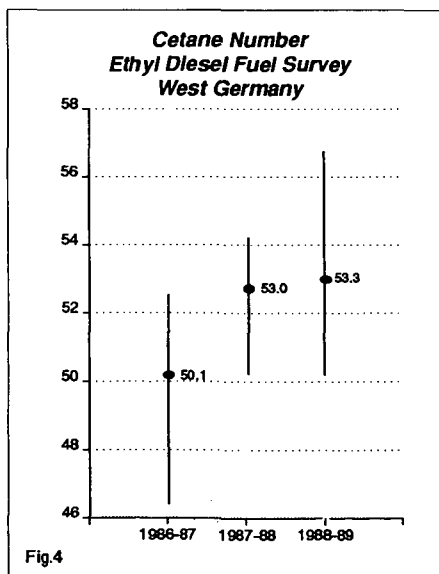


Fig.4

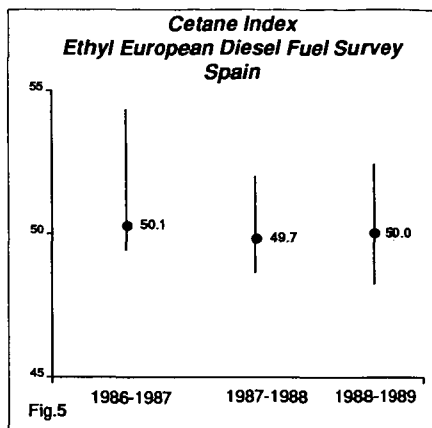


Fig.5

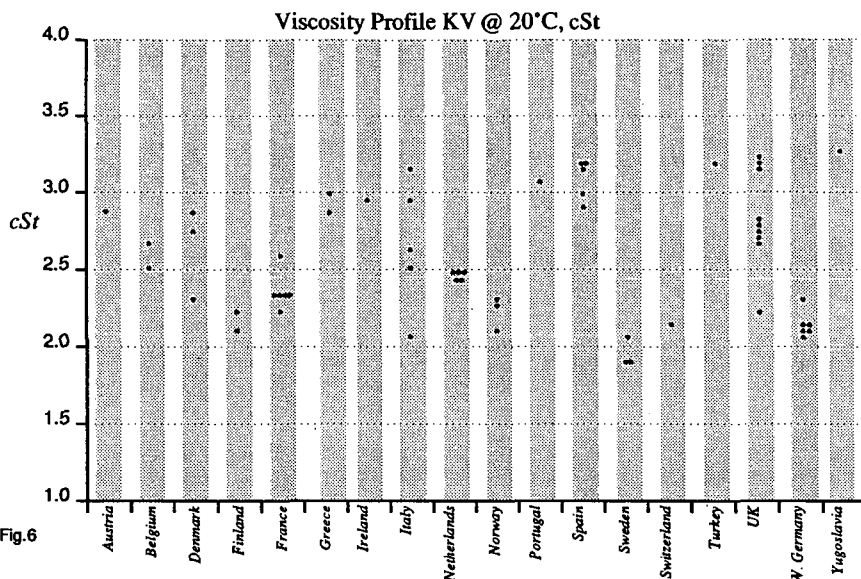
## Cetane Index

This is an attempt to empirically predict a fuels ignition quality based on its density and boiling range. As this shows reasonable agreement with a fuels natural cetane it is arguably a better indicator of the European cetane pool than cetane number. And indeed this is unchanged across the 3 year period. However in Spain (Fig 5) both demand and refinery conversion is increasing whilst crude slate has resulted in lower natural indices and numbers. Thus cetane index has fallen steadily despite cetane number remaining high due to legislation of a 50 Cetane Number minimum but a 45 Cetane Index minimum thereby allowing refiners greater flexibility.

## Viscosity

Viscosity variations have similar effects to those described for density. Additionally at low viscosities, below about 3 cSt @ 20°C, pumping leakage is increased with hot re-starts becoming difficult under hot ambient conditions, reduced power output and pump lubrication becoming critical. The combination of wide viscosity band variations with wide density variations exacerbates emission levels and vehicle performance.

## Ethyl European Diesel Fuel Survey - Winter 1988/89



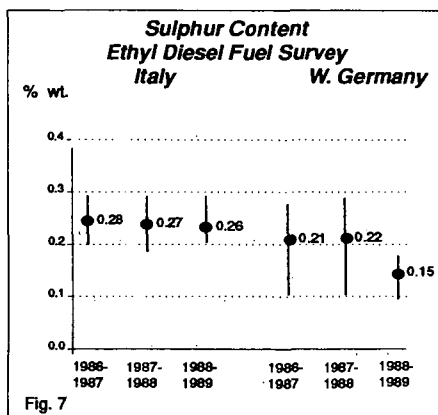
There is some evidence (Table 1) for a general lightening of diesel fuel in Europe as a consequence of lower Cloud points. We do not see wide viscosity variations in Europe (Fig 6) and it is important to note this parameter is not a constraint since it is controlled indirectly by other diesel fuel properties such as Cloud Point, Density and Distillation range.

## Aromatics Content

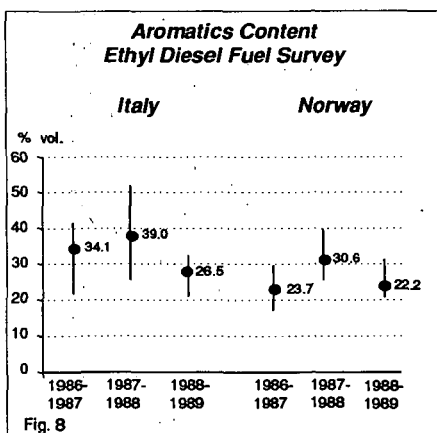
Aromatics, have been considered in certain studies to relate to deleterious emissions, particularly particulates. Several studies (Ref 5) claim to show links between the aromatics content of a diesel fuel and exhaust particulate emissions. Consideration is being

## Sulphur Content

Worldwide concerns about "acid-rain" have resulted in legislation designed to control acidic emissions, most notably oxides of sulphur. Additionally the need for low sulphur fuel for satisfactory operation of low emissions oxidation catalyst equipped diesel vehicles is supporting this drive. The Californian standard of 0.05% max weight is the level that OEM's are requiring. In Europe the typical limit of 0.30% weight has moved down to 0.20% weight in the more environmentally sensitive countries. A good example of this is to contrast the sulphur contents in Italy and West Germany (Fig 7). This is placing increasing pressure on available refinery hydrotreating capacity and penalising higher sulphur crudes.

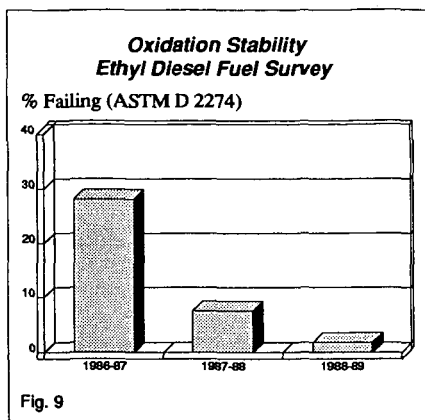


given within the European Economic Community to follow the US example and limit the aromatics level of road diesel. Also being investigated is the best method for measuring the aromatics as the F.I.A. Method (ASTM D1319) often gives poor separation with heavier boiling European fuels (85% @ 350°C min is the common European limit). Whilst Table 1 would suggest there might be some overall decrease in aromatics levels in Europe it varies significantly country to country. Thus the high degree of conversion stream usage and heavier crude processing/higher distillation range is reflected in the high aromatics levels in Italy versus those of Norway (Fig 8), particularly pre-1988-89.



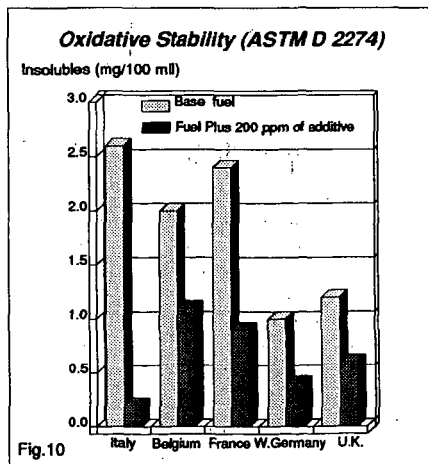
## Olefin Content

Olefin levels in diesel are generally low however in terms of fuel stability they are regularly cited (Ref 6) as significant. It is thus interesting to note that every year from 1986 to 1989 the overall olefin level has doubled in Europe although the total percentage remains very small. Again this reflects the increasing use of conversion streams and level of hydrotreatment.



## Oxidation Stability

Oxidation stability is widely considered to be an important parameter in determining the long term storage stability of a fuel. It is typically evaluated using the ASTM D2274 test developed by the US Navy. The limit for satisfactory field performance is usually taken as 1.5 mg/100 ml of insolubles. Figure 9 shows that the percentage of fuels with deposit levels above 1.5 mg/100 ml has fallen to negligible



### Oxidation Stability v Thermal Stability Ethyl Diesel Fuel Survey 1988/89

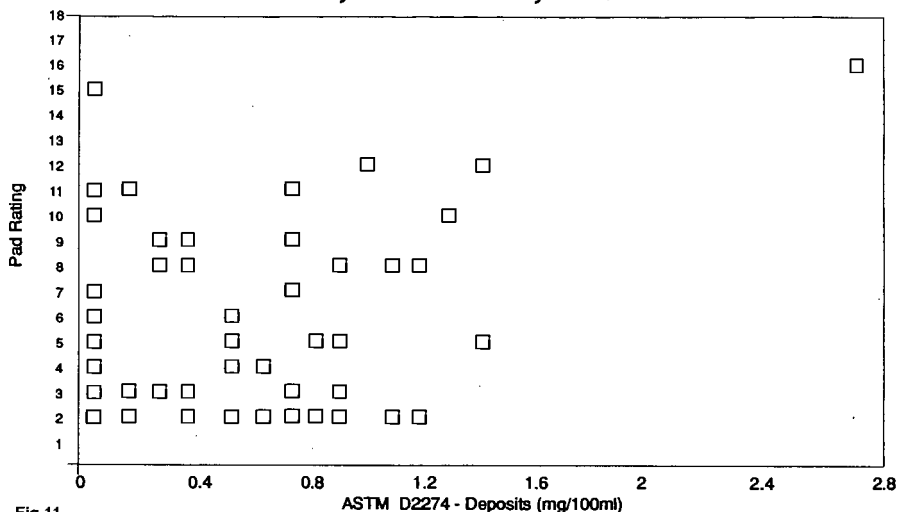


Fig. 11

levels. This is thought to be due to the increasing use of multifunctional additive packages offering stability enhancement. An example of their effect is shown in Fig 10. This may also help explain the lack of an obvious relationship between thermal and oxidative stability (Fig 11).

## Thermal Stability

Thermal stability whilst important in determining a fuels long term storage stability has also been linked to nozzle coking tendency (Ref 7). It is usually measured by some form of rapid thermal shock test followed by filtration and assessment of the filter deposits. Using the Ethyl Pad Procedure; where a rating of 20 is a black filter, 0 is clean and 7 is the maximum for good field performance we have observed results from 2 to 20 in our surveys. Previous work has suggested possible correlation with nozzle coking tendency, (Ref 8), surveys.

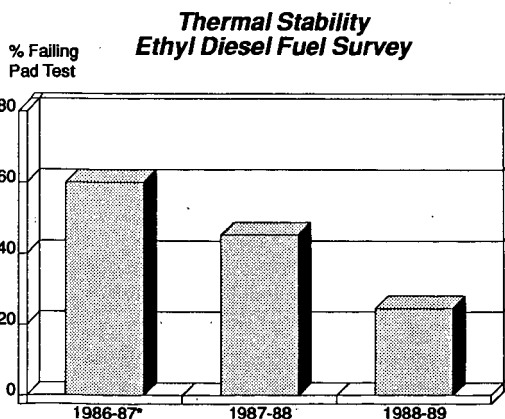


Fig. 12 \* ( limited data-base)

Just as for oxidation stability the percentage of samples with ratings above 7 has declined steadily from 1986-89 (Fig 12). This is also surprising when viewed against the background of increasing olefin levels. Again the use of multifunctional additive packages is improving fuel stability. This also tallies with the poor agreement between olefin content and Pad Rating (Fig 13).

***Olefin Content v Thermal Stability  
Ethyl Diesel Fuel Survey 1988/89***

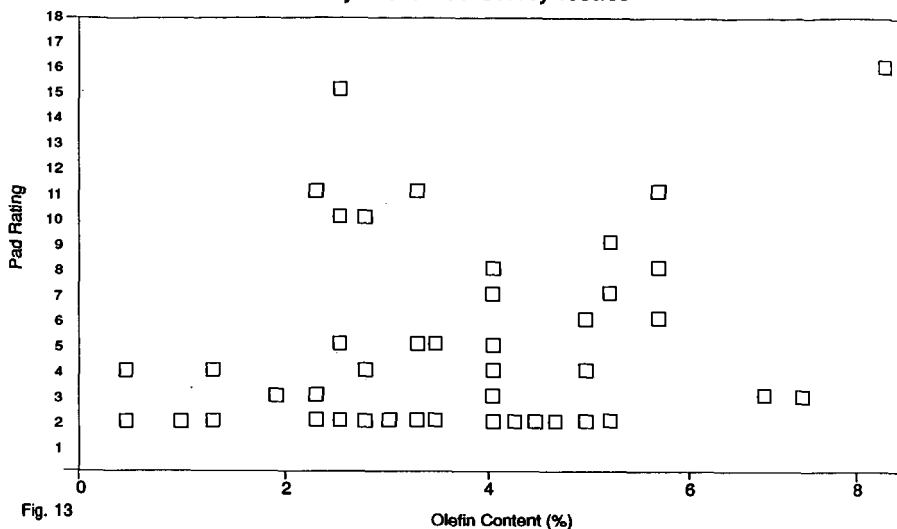


Fig. 13

## Conclusions

The data reported in this paper indicate:

- 1) Diesel fuel quality remains high in Europe due in part to the increasing use of multifunctional diesel fuel additive packages
- 2) As a result of these marketing factors cetane number is increasing.
- 3) Sulphur levels are declining throughout Europe.
- 4) Olefin levels are increasing.
- 5) Oxidative and thermal stability are improving overall in Europe primarily due to the use of multifunctional diesel fuel additive packages.

## References

- 1) Ethyl European Diesel Fuel Survey Winter 1986-87
- 2) Ethyl European Diesel Fuel Survey Winter 1987-88
- 3) Ethyl European Diesel Fuel Survey Winter 1988-89
- 4) H.A. Henein and J.A. Bolt; SAE 67007
- 5) E.G. Barry and L.J. McCabe, D.H. Gerke and J.M. Perez; SAE 852078
- 6) M.W. Schrepfer, R.J. Arnold and C.A. Stansky, Oil and Gas Journal, January 16, 1984
- 7) M. Fortmagel and B. Herrbrich, API, New Orleans, 1984
- 8) P.B. Mabley and G.M. Wallace, Third International Stability and Handling of Liquid Fuels Conference, London, 1988



# European National Specifications For Diesel Fuel

| Country     | Spec. Ref.           | Density<br>Kg/l | Distill., °C                                    | KV @ 20°C, cSt          | FL Pt., °C | CLP <sub>1</sub> , °C                     | CFPP, °C                                    | Pour Pt., °C                                | Sulphur,<br>% Wt.          | Cetane<br>Index              | Cetane<br>Number |
|-------------|----------------------|-----------------|---|-------------------------|------------|---|---|---|----------------------------|------------------------------|------------------|
| Austria     | Ö Norm C1104         | 0.820-0.860     | Min 85% @ 350                                   | 3.0 - 8.0               | 56 min     | -   | -15 - -22 max (W)                           | -   | 0.15 max                   | -                            | 48 min           |
| Belgium     | NBN T32-713          | 0.820-0.870     | Max 65% @ 250<br>Min 85% @ 350                  | 4.0 max @ 40°C          | 56 min     | -   | -15 max (W)                                 | -   | 0.2 max                    | -                            | 46 min           |
| France      | CSR 05-M             | 0.810-0.890     | Max 65% @ 250<br>Min 85% @ 350                  | 9.5 max                 | 55-120     | -5 max (W)<br>-8 max (W)*<br>*Grand Froid | -15 max (W)<br>-18 max (W)*<br>*Grand Froid | -18 max (W)<br>-21 max (W)*<br>*Grand Froid | 0.3 max                    | -                            | 48 min           |
| Greece      | 734/AB/86            | Report          | Min 85% @ 350<br>Max FBP @ 370 Athens           | 2 - 6 @ 37.8°C          | 55 min     | -   | -5 max (W)<br>-2 max Athens (W)             | -9 max (W)<br>-6 max Athens (W)             | 0.3 max                    | 47 min Athens<br>45 min Rest | -                |
| Ireland     | 1.8.251:1981         | 0.825 min       | Min 85% @ 350<br>Max FBP @ 380                  | 2.0 min. @ 40°C         | 61 min     | -2 max (W)                                | -12 max (W)                                 | -   | 0.3 max                    | 50 min                       | 50 min           |
| Italy       | NCK30-01             | 0.8030-865      | Max 65% @ 250<br>Min 85% @ 350                  | 2.0-5.33 @ 37.8°C       | 55 min     | -   | -10 max (W)                                 | -6 max (W)                                  | 0.3 max<br>0.2 max (cides) | 48 min                       | 47 min           |
| Portugal    | 124/89               | 0.815-0.865     | Max 65% @ 250<br>Min 85% @ 350                  | 1.8-5.5 @ 40°C          | 56 min     | -   | -6 max (W)                                  | -   | 0.3 max                    | 45 min                       | -                |
| Spain       | Decreto<br>1485/1987 | 0.825-0.860     | Max 65% @ 250<br>Min 90% @ 350<br>Max FBP @ 380 | 4.5 max @ 37.8°C<br>(W) | 55 min     | -1 max (W)                                | -8 max (W)                                  | -   | 0.3 max                    | 45 min                       | 50 min           |
| Sweden      | S315 S432            | 0.800-0.860     | Min 10% @ 230<br>Min 90% @ 360                  | 1.5-4.0 @ 40°C          | 40 min     | -10 max (W)                               | -20 max (W)                                 | -   | 0.3 max<br>0.2 mean        | 45 min                       | 45 min           |
| Switzerland | SN181160/1           | 0.815-0.845     | Min 90% @ 360                                   | 2.5 - 6.0               | 55 min     | -6 max (W)                                | -15 max (W)                                 | -15 max (W)                                 | 0.2 max                    | 48 min                       | 48 min           |
| Turkey      | TSE                  | 0.850 max       | Min 90% @ 363<br>FBP 391 max                    | 1.0-6.0 @ 37.8°C        | 52 min     | -   | -   | Report                                      | 1.0 max                    | 50 * min<br>*Diesel<br>Index | -                |
| U.K.        | BS 2869              | 0.835-0.865     | Min 50% @ 310<br>Min 85% @ 350                  | 2.5-5.0 @ 40°C          | 56 min     | -   | -15 max (W)                                 | -   | 0.3 max                    | 46 min                       | 48 min           |
| W. Germany  | DIN 51601            | 0.820-0.860     | Max 65% @ 250<br>Min 85% @ 350                  | 2.0 - 8.0               | 56 min     | -   | -15 max (W)                                 | -   | 0.2 max                    | -                            | 45 min           |
| Yugoslavia  | JUS B.312.410        | 0.810-0.860     | Min 90% @ 360                                   | 1.8-9.0                 | 55 min     | -   | -9 max (W)                                  | -   | 1.0 max                    | -                            | 45 min           |

N. B. (W) is Winter

Ethyl European Diesel Fuel Survey

Winter 1988/89

|            |           |            |            |            |            |                 |           |           |
|------------|-----------|------------|------------|------------|------------|-----------------|-----------|-----------|
| ASTM D1298 | ASTM D445 | ASTM D1319 | ASTM D4294 | ASTM D1319 | ASTM D2274 | <i>Pad Test</i> | ASTM D976 | ASTM D613 |
|------------|-----------|------------|------------|------------|------------|-----------------|-----------|-----------|

<https://doi.org/10.1093/bioinformatics/btad678>

## Greece

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 013      | 0.8423  | 5.19      | 32.1        | 0.4       | 0.48      | 2.0         | 16           | 52.8 | 51.2 |
| 014      | 0.8371  | 4.66      | 29.6        | 0.4       | 0.32      | 2.0         | 17           | 52.8 | 53.8 |

## Italy

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 015      | 0.8472  | 5.39      | 41.5        | 0.4       | 0.28      | 1.8         | 16           | 52.3 | 50.6 |
| 016      | 0.8180  | 3.03      | 21.5        | 0.2       | 0.26      | 1.4         | -            | 54.7 | 53.8 |
| 017      | 0.8493  | 5.20      | 41.1        | 0.4       | 0.27      | 2.0         | 5            | 50.2 | 49.4 |
| 018      | 0.8450  | 5.49      | 41.9        | 0.4       | 0.29      | 1.8         | 4            | 52.9 | 52.0 |
| 019      | 0.8262  | 3.98      | 24.7        | 0.5       | 0.30      | 1.4         | -            | 56.5 | 55.5 |

## Netherlands

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 020      | 0.8337  | 3.90      | 26.5        | 0.4       | 0.23      | 0.8         | -            | 54.4 | 53.7 |
| 021      | 0.8283  | 3.75      | 25.9        | 0.4       | 0.17      | -           | 53.1         | 54.1 | -    |
| 022      | 0.8264  | 3.93      | 23.0        | 0.4       | 0.23      | 0.8         | -            | 55.1 | 54.4 |
| 023      | 0.8313  | 3.47      | 33.1        | 0.4       | 0.07      | 1.2         | -            | 50.8 | 51.4 |
| 024      | 0.8456  | 4.22      | 26.7        | 0.4       | 0.18      | 1.2         | -            | 45.1 | 45.3 |

## Norway

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 025      | 0.8336  | 3.34      | 28.8        | 0.5       | 0.29      | 1.2         | -            | 50.9 | 49.2 |
| 026      | 0.8247  | 2.69      | 19.5        | 0.5       | 0.10      | 1.0         | -            | 47.8 | 49.0 |
| 027      | 0.8276  | 3.19      | 22.9        | 0.4       | 0.10      | 1.0         | -            | 50.5 | 50.4 |

## Portugal

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 028      | 0.8438  | 7.02      | 33.8        | 0.4       | 0.46      | 1.6         | -            | 54.2 | 54.6 |

## Spain

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 029      | 0.8491  | 4.80      | 36.7        | 0.4       | 0.31      | 2.8         | 18           | 49.2 | 49.6 |
| 030      | 0.8290  | 4.16      | 25.4        | 0.4       | 4.16      | 3.4         | 3            | 54.4 | 53.9 |
| 031      | 0.8447  | 5.20      | 27.9        | 0.4       | 0.38      | 0.8         | -            | 51.6 | 52.4 |
| 032      | 0.8483  | 4.94      | 28.9        | 0.4       | 0.35      | 1.6         | -            | 49.2 | 50.0 |

## Sweden

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 033      | 0.8338  | 4.04      | 27.9        | 0.4       | 0.16      | 1.3         | -            | 53.1 | 53.8 |
| 034      | 0.8305  | 3.10      | 22.0        | 0.4       | 0.19      | 0.8         | -            | 48.5 | 49.0 |
| 035      | 0.8352  | 3.47      | 24.3        | 0.4       | 0.23      | 1.5         | -            | 49.5 | 49.4 |

## United Kingdom

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 036      | 0.8438  | 4.77      | 27.7        | 0.4       | 0.15      | 2.4         | -            | 50.9 | 51.9 |
| 037      | 0.8476  | 4.98      | 29.2        | 0.4       | 0.23      | 0.8         | -            | 50.1 | 50.1 |
| 038      | 0.8457  | 4.74      | 28.8        | 0.4       | 0.09      | 0.8         | -            | 50.4 | 50.9 |
| 039      | 0.8484  | 5.67      | 31.8        | 0.4       | 0.20      | 0.8         | -            | 52.5 | 53.6 |
| 040      | 0.8370  | 4.44      | 28.2        | 0.4       | 0.19      | 2.3         | 11           | 52.2 | 52.2 |
| 041      | 0.8449  | 5.00      | 30.0        | 1.9       | 0.18      | 0.8         | -            | 52.2 | 52.6 |
| 042      | 0.8412  | 4.73      | 28.4        | 0.4       | 0.21      | 1.5         | -            | 52.5 | 53.6 |
| 043      | 0.8494  | 5.64      | 31.0        | 0.4       | 0.27      | 1.0         | -            | 50.9 | 50.7 |
| 044      | 0.8428  | 4.51      | 30.0        | 0.4       | 0.22      | 0.8         | -            | 50.2 | 50.5 |

## W. Germany

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 045      | 0.8336  | 3.83      | 25.5        | 0.4       | 0.13      | 0.8         | -            | 50.8 | 50.6 |
| 046      | 0.8392  | 3.84      | 29.6        | 0.4       | 0.24      | 0.8         | -            | 46.8 | 46.7 |
| 047      | 0.8292  | 3.65      | 21.8        | 0.4       | 0.19      | 1.0         | -            | 54.6 | 52.7 |
| 048      | 0.8273  | 3.63      | 21.3        | 0.4       | 0.25      | 2.0         | 20           | 52.8 | 51.3 |
| 049      | 0.8350  | 3.44      | 25.9        | 0.4       | 0.28      | 0.8         | -            | 47.9 | 46.6 |
| 050      | 0.8259  | 3.35      | 21.6        | 0.4       | 0.17      | 0.8         | -            | 51.7 | 52.9 |

# Ethyl Diesel Fuel Survey Winter 1987/88

ASTM D1298 ASTM D445 ASTM D1319 ASTM D4294 ASTM D1319 ASTM D2274 Pad Test ASTM D976 ASTM D613

## Austria

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 001      | 0.8377  | 4.09      | 27.8        | 1.3       | 0.17      | 0.9         | 4            | 49.7 | 49.1 |

## Belgium

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 002      | 0.8390  | 4.38      | 36.2        | 0.9       | 0.21      | 0.9         | 9            | 51.7 | 51.7 |
| 003      | 0.8463  | 4.40      | 34.1        | 2.7       | 0.25      | 0.9         | 7            | 48.7 | 48.6 |

## Denmark

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 004      | 0.8392  | 4.01      | 28.1        | 4.3       | 0.20      | 0.8         | 3            | 50.2 | 56.7 |
| 1092     | 0.8565  | 5.06      | 39.3        | 1.5       | 0.17      | 0.8         | 14           | 47.2 | 44.9 |

## Finland

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 006      | 0.8380  | 3.33      | 32.7        | 2.0       | 0.11      | 0.7         | 14           | 46.4 | 49.6 |
| 007      | 0.8397  | 3.34      | 34.3        | 1.8       | 0.13      | 1.2         | 46.3         | 49.8 |      |

## France

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 008      | 0.8335  | 3.48      | 30.3        | 0.4       | 0.28      | 0.9         | 7            | 50.0 | 48.5 |
| 009      | 0.8374  | 3.83      | 30.3        | 0.5       | 0.33      | 0.8         | 10           | 50.1 | 49.0 |
| 010      | 0.8287  | 3.83      | 26.5        | 0.7       | 0.26      | 0.9         | 10           | 54.3 | 51.6 |
| 011      | 0.8308  | 3.58      | 25.9        | 0.8       | 0.23      | 0.9         | 2            | 51.4 | 52.3 |
| 012      | 0.8395  | 4.35      | 32.5        | 1.3       | 0.32      | 0.7         | 8            | 51.4 | 50.4 |
| 013      | 0.8328  | 3.86      | 29.0        | 1.0       | 0.31      | 0.9         | 7            | 50.7 | 48.9 |

## Greece

| Code No. | Density | KV @ 20 °C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|------------|-------------|-----------|-----------|-------------|--------------|------|------|
| 014      | 0.8426  | 4.84       | 32.8        | 2.3       | 0.50      | 1.2         | 16           | 51.9 | 50.9 |
| 015      | 0.8418  | 5.87       | 33.7        | 0.8       | 0.29      | 0.8         | 3            | 54.7 | 53.5 |

## Italy

| Code No. | Density | KV @ 20 °C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|------------|-------------|-----------|-----------|-------------|--------------|------|------|
| 016      | 0.8415  | 4.82       | 39.1        | 1.3       | 0.25      | 4.3         | 14           | 51.9 | 49.3 |
| 017      | 0.8272  | 2.97       | 27.0        | 4.8       | 0.19      | 0.9         | 15           | 49.1 | 48.1 |
| 018      | 0.8499  | 5.62       | 52.1        | 4.8       | 0.30      | 0.9         | 14           | 51.7 | 48.7 |
| 019      | 0.8461  | 4.45       | 44.1        | 1.8       | 0.30      | 2.3         | 14           | 48.9 | 50.9 |
| 020      | 0.8362  | 5.20       | 32.8        | 0.8       | 0.29      | 2.6         | 14           | 55.4 | 55.7 |

## Netherlands

| Code No. | Density | KV @ 20 °C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|------------|-------------|-----------|-----------|-------------|--------------|------|------|
| 021      | 0.8474  | 4.32       | 34.4        | 1.1       | 0.27      | 1.0         | 2            | 49.9 | 51.4 |
| 022      | 0.8365  | 3.93       | 28.2        | 1.0       | 0.21      | 0.8         | 2            | 51.3 | 49.9 |
| 023      | 0.8281  | 4.15       | 30.1        | 3.8       | 0.26      | 0.8         | 3            | 53.4 | 52.9 |
| 024      | 0.8355  | 3.77       | 29.7        | 2.9       | 0.21      | 0.9         | 2            | 51.0 | 49.8 |
| 025      | 0.8403  | 4.17       | 32.7        | 2.2       | 0.28      | 0.9         | 3            | 50.7 | 53.1 |

## Norway

| Code No. | Density | KV @ 20 °C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|------------|-------------|-----------|-----------|-------------|--------------|------|------|
| 026      | 0.8454  | 3.80       | 31.4        | 1.6       | 0.17      | 0.8         | 6            | 46.7 | 47.0 |
| 027      | 0.8300  | 3.23       | 26.5        | 0.9       | 0.19      | 0.9         | 3            | 49.4 | 50.7 |
| 028      | 0.8384  | 3.56       | 34.0        | 0.6       | 0.13      | 0.8         | 7            | 49.0 | 48.9 |

## Portugal

| Code No. | Density | KV @ 20 °C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|------------|-------------|-----------|-----------|-------------|--------------|------|------|
| 029      | 0.8411  | 5.55       | 34.0        | 0.6       | 0.46      | 0.9         | 7            | 53.6 | 54.6 |

## Spain

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 030      | 0.8555  | 5.43      | 38.5        | 0.7       | 0.50      | 0.9         | 1            | 47.9 | 51.2 |
| 031      | 0.8411  | 4.54      | 35.8        | 2.1       | 0.49      | 1.2         | 1            | 51.2 | 52.4 |
| 032      | 0.8466  | 5.21      | 36.5        | 1.8       | 0.42      | 0.9         | -            | 50.8 | 50.7 |
| 033      | 0.8590  | 5.80      | 49.8        | 2.1       | 0.42      | 0.7         | -            | 48.8 | 47.2 |

## Sweden

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 034      | 0.8282  | 3.22      | 25.6        | 1.0       | 0.19      | 0.8         | 8            | 50.6 | 52.0 |
| 035      | 0.8285  | 2.89      | 24.7        | 1.0       | 0.12      | 0.9         | 19           | 46.6 | 50.9 |
| 036      | 0.8411  | 3.50      | 33.6        | 1.1       | 0.19      | 0.8         | 14           | 46.9 | 48.8 |

## Switzerland

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 037      | 0.8297  | 3.35      | 26.2        | 1.0       | 0.16      | 0.7         | 10           | 51.1 | 49.9 |

## United Kingdom

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 038      | 0.8467  | 5.58      | 39.8        | 1.1       | 0.19      | 0.9         | 3            | 51.9 | 49.1 |
| 039      | 0.8494  | 4.54      | 35.9        | 0.7       | 0.22      | 1.8         | 12           | 48.3 | 49.6 |
| 040      | 0.8461  | 4.38      | 33.6        | 1.2       | 0.05      | 0.8         | 5            | 48.9 | 48.7 |
| 041      | 0.8510  | 5.55      | 38.6        | 1.5       | 0.23      | 0.9         | 2            | 51.3 | 50.9 |
| 042      | 0.8497  | 4.97      | 36.8        | 0.6       | 0.20      | 0.9         | 14           | 50.9 | 51.2 |
| 043      | 0.8434  | 4.82      | 29.6        | 1.4       | 0.23      | 0.8         | 3            | 51.5 | 51.7 |
| 044      | 0.8483  | 4.30      | 34.3        | 1.3       | 0.15      | 0.9         | 1            | 49.6 | 50.8 |
| 045      | 0.8418  | 4.41      | 31.3        | 1.3       | 0.24      | 0.8         | 5            | 52.0 | 50.1 |
| 046      | 0.8467  | 5.58      | 40.6        | 3.2       | 0.20      | 0.8         | 8            | 52.9 | 54.1 |

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Slab | Thermal Slab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 047      | 0.8302  | 3.35      | 26.5        | 1.2       | 0.13      | 0.8         | 3            | 47.4 | 51.9 |
| 048      | 0.8337  | 3.54      | 32.8        | 1.4       | 0.26      | 0.8         | 3            | 49.4 | 50.1 |
| 049      | 0.8215  | 3.27      | 23.2        | 1.0       | 0.27      | 0.8         | 2            | 52.5 | 54.4 |
| 050      | 0.8232  | 3.34      | 23.7        | 1.6       | 0.26      | 0.9         | 3            | 50.8 | 54.0 |
| 051      | 0.8286  | 3.11      | 26.8        | 0.6       | 0.29      | 0.9         | 10           | 48.0 | 54.1 |
| 052      | 0.8287  | 3.25      | 26.2        | 1.9       | 0.13      | 0.7         | 3            | 49.1 | 53.5 |

| Yugoslavia |         |           |             |           |           |             |              |      |      |
|------------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| Code No.   | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide. Stab | Thermal Stab | CI   | CN   |
| 053        | 0.8338  | 4.27      | 29.1        | 1.5       | 0.65      | 0.9         | 3            | 52.7 | 53.6 |



# Ethyl Diesel Fuel Survey Winter 1988/89

ASTM D1298 ASTM D445 ASTM D1319 ASTM D4294 ASTM D1319 ASTM D2274 Pd Test ASTM D976 ASTM D613

## Austria

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 001      | 0.8426  | 4.42      | 29.7        | 4.6       | 0.14      | 0.8         | 2            | 50.5 | 53.8 |

## Belgium

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 002      | 0.8429  | 4.51      | 32.5        | 5.6       | 0.17      | 0.5         | 6            | 51.4 | 50.6 |
| 003      | 0.8402  | 4.22      | 28.5        | 4.3       | 0.23      | 0.7         | 7            | 52.7 | 49.2 |

## Denmark

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 004      | 0.8461  | 4.37      | 22.6        | 4.1       | 0.18      | 0.5         | 5            | 49.1 | 49.4 |
| 005      | 0.8437  | 4.21      | 26.6        | 1.5       | 0.17      | 0.6         | 4            | 50.2 | 48   |
| 006      | 0.8222  | 3.37      | 21.8        | 1.8       | 0.20      | 0.8         | 5            | 53.6 | 53.2 |

## Finland

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 007      | 0.8379  | 3.30      | 30.3        | 0.7       | 0.07      | 0.4         | 2            | 47.2 | 50.1 |
| 008      | 0.8384  | 3.46      | 31.9        | 0.9       | 0.08      | 0.8         | 4            | 48.1 | 51   |

## France

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 009      | 0.8365  | 3.91      | 28.4        | 4.4       | 0.26      | 0.1         | 4            | 53.0 | 51.7 |
| 010      | 0.8318  | 3.41      | 23.0        | 2.8       | 0.32      | 0.1         | 10           | 52.0 | 53.4 |
| 011      | 0.8346  | 3.80      | 28.0        | 3.6       | 0.19      | 0.4         | 3            | 52.8 | 51.8 |
| 012      | 0.8289  | 3.69      | 26.1        | 3.6       | 0.15      | 0.2         | 11           | 52.8 | 51.8 |
| 013      | 0.8276  | 3.59      | 21.0        | 5.4       | 0.35      | 0.6         | 2            | 54.7 | 54.7 |
| 014      | 0.8321  | 3.47      | 22.8        | 5.3       | 0.30      | 0.1         | 7            | 52.6 | 51.1 |

## Greece

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide, Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 015      | 0.8482  | 5.35      | 32.4        | 4.3       | 0.48      | 0.9         | 8            | 51.5 | 56.9 |
| 016      | 0.8278  | 4.50      | 17.8        | 3.8       | 0.21      | 1.5         | 12           | 57.1 | 56.9 |

## Ireland

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide, Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 017      | 0.8493  | 4.49      | 31.7        | 4.0       | 0.17      | 1.3         | 10           | 50.3 | 52.7 |

## Italy

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide, Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 018      | 0.8413  | 4.64      | 32.4        | 3.3       | 0.26      | 1.1         | 2            | 52.2 | 52.6 |
| 019      | 0.8255  | 3.64      | 20.8        | 8.4       | 0.25      | 2.7         | 16           | 55.0 | 53.1 |
| 020      | 0.8358  | 4.60      | 27.5        | 7.0       | 0.24      | 0.9         | 3            | 54.6 | 54.7 |
| 021      | 0.8289  | 3.91      | 21.7        | 5.3       | 0.26      | 0.7         | 9            | 55.7 | 55.3 |
| 022      | 0.8379  | 3.92      | 30.0        | 3.7       | 0.30      | 1.0         | 12           | 52.1 | 54.2 |

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## Netherlands

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide, Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 023      | 0.8362  | 3.76      | 25.1        | 4.1       | 0.20      | 0.7         | 3            | 52.1 | 52.8 |
| 024      | 0.8268  | 3.63      | 22.5        | 3.1       | 0.16      | 0.5         | 2            | 54.3 | 52.9 |
| 025      | 0.8234  | 3.67      | 22.2        | 5.1       | 0.16      | 0.1         | 4            | 56.0 | 55.4 |
| 026      | 0.8368  | 3.54      | 31.0        | 4.4       | 0.14      | 0.9         | 3            | 52.3 | 52.2 |
| 027      | 0.8375  | 4.18      | 24.8        | 4.7       | 0.19      | 0.2         | 2            | 51.6 | 52.2 |

## Norway

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxide, Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 028      | 0.8351  | 3.45      | 23.1        | 2.9       | 0.12      | 0.4         | 2            | 50.2 | 51.5 |
| 029      | 0.8283  | 3.15      | 20.8        | 2.6       | 0.10      | 0.8         | 2            | 47.8 | 51.6 |
| 030      | 0.8355  | 3.11      | 22.8        | 3.4       | 0.10      | 0.1         | 2            | 48.0 | 50.6 |

# Portugal

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 031      | 0.8379  | 5.51      | 28.6        | 4.4       | 0.49      | 0.2         | 2            | 54.6 | 56.9 |

# Spain

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 032      | 0.8429  | 4.77      | 26.2        | 2.8       | 0.41      | 0.1         | 2            | 51.0 | 54.3 |
| 033      | 0.8509  | 5.16      | 36.2        | 3.6       | 0.44      | 0.2         | 3            | 50.7 | 51.6 |
| 034      | 0.8567  | 4.98      | 33.5        | 5.7       | 0.45      | 0.7         | 11           | 47.5 | 53.9 |
| 035      | 0.8514  | 5.01      | 38.0        | 3.8       | 0.52      | 0.9         | 5            | 49.4 | 51.6 |
| 036      | 0.8463  | 5.30      | 35.6        | 5.0       | 0.44      | 1.2         | 2            | 51.6 | 52.8 |

# Sweden

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 037      | 0.8257  | 2.70      | 23.2        | 1.1       | 0.12      | 0.7         | 2            | 46.0 | 46.5 |
| 038      | 0.8295  | 3.15      | 26.8        | 1.1       | 0.09      | 0.6         | 2            | 48.0 | 48.8 |
| 039      | 0.8239  | 2.85      | 22.5        | 1.5       | 0.17      | 0.7         | 2            | 48.2 | 47.9 |

# Switzerland

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 040      | 0.8281  | 3.18      | 19.7        | 5.1       | 0.11      | 0.1         | 6            | 50.6 | 52.7 |

# Turkey

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 041      | 0.8391  | 4.27      | 26.6        | 3.7       | 0.72      | 0.4         | 3            | 53.7 | 53.7 |

# United Kingdom

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxida. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 042      | 0.8462  | 4.39      | 28.3        | 3.5       | 0.16      | 0.1         | 5            | 51.1 | 51.8 |
| 043      | 0.8408  | 4.21      | 28.1        | 3.1       | 0.18      | 0.5         | 4            | 48.7 | 51   |
| 044      | 0.8506  | 4.16      | 32.3        | 4.0       | 0.06      | 0.3         | 9            | 47.9 | 52.2 |
| 045      | 0.8453  | 4.52      | 27.7        | 4.5       | 0.20      | 0.1         | 2            | 51.6 | 53.3 |

## United Kingdom (continued)

| Code No. | Density | KV @ 20°C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|-----------|-------------|-----------|-----------|-------------|--------------|------|------|
| 046      | 0.8473  | 4.42      | 31.4        | 3.9       | 0.17      | 50.2        | 49.6         |      | 54.3 |
| 047      | 0.8337  | 4.50      | 24.6        | 2.9       | 0.18      | 0.1         | 15           | 55.4 | 54.3 |
| 048      | 0.8403  | 4.18      | 27.5        | 3.8       | 0.16      | 0.1         | 3            | 52.7 | 55.4 |
| 049      | 0.8455  | 4.58      | 33.3        | 2.6       | 0.25      | 0.1         | 3            | 51.3 | 55.3 |
| 050      | 0.8453  | 4.34      | 32.4        | 3.5       | 0.17      | 0.1         | 11           | 49.4 | 51.6 |

## West Germany

| Code No. | Density | KV @ 20 °C | % Aromatics | % Olefins | % Sulphur | Oxidn. Stab | Thermal Stab | CI   | CN   |
|----------|---------|------------|-------------|-----------|-----------|-------------|--------------|------|------|
| 051      | 0.8285  | 3.24       | 23.2        | 4.1       | 0.12      | 0.9         | 2            | 50.8 | 56.8 |
| 052      | 0.8238  | 3.02       | 19.7        | 4.4       | 0.17      | 0.1         | 3            | 49.7 | 52.4 |
| 053      | 0.8244  | 3.06       | 23.3        | 2.5       | 0.16      | 0.3         | 3            | 49.2 | 54.5 |
| 054      | 0.8232  | 3.01       | 19.7        | 6.8       | 0.16      | 0.2         | 3            | 49.4 | 53.1 |
| 055      | 0.8371  | 3.39       | 31.2        | 2.9       | 0.17      | 1.5         | 5            | 47.2 | 50.2 |
| 056      | 0.8287  | 3.45       | 20.3        | 4.0       | 0.10      | 0.3         | 3            | 51.4 | 53.1 |

# Yugoslavia

| <i>Code No.</i> | <i>Density</i> | <i>KV @ 20°C</i> | <i>% Aromatics</i> | <i>% Olefins</i> | <i>% Sulphur</i> | <i>Oxidn. Stab</i> | <i>Thermal Stab</i> | <i>CI</i> | <i>CN</i> |
|-----------------|----------------|------------------|--------------------|------------------|------------------|--------------------|---------------------|-----------|-----------|
| 057             | 0.8440         | 4.64             | 31.8               | 5.7              | 0.90             | 0.5                | 8                   | 56.3      | 53.6      |